

Review on Potential Use of Fruit and Vegetables By-Products as A Valuable Source of Natural Food Additives

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Abstract
Food processing industry including fruit and vegetable processing is the second largest generator of wastes into the environment only after the household sewage. A huge amount of waste in the form of liquid and solid is produced in the fruit and vegetable processing industries, which contains many reusable substances of high value with large economic potential. The processing of fruits and vegetables results in high amounts of waste materials such as peels, seeds, stones, and unused flesh generated in the different steps of the processing chains. It causes pollution problem if not utilized or disposed-off properly. A disposal of these materials usually represents a problem that is further aggravated by legal restrictions. However, this Waste product, which is thrown into the environment, is rich in valuable compounds. They are novel, natural and economic sources of flavoring, colorants, protein, dietary fiber, antimicrobials and antioxidants, which can be used in the food industry as a source of natural food additives. Thus, new aspects concerning the use of these by-products for further exploitation on the production of food additives or supplements with high nutritional value have gained increasing interest because these are high-value products and their recovery may be economically attractive. The main purpose of this review is to promote the production and processing of fruits and vegetable highlighting the possibility of extracting bioactive compounds from fruit and vegetable wastes and possibility to use them as natural additives for food industry. These all benefits will open up as a scope for future utilization of fruit and vegetable waste for therapeutic and Nutraceuticals purpose.
Keywords: fruit and vegetables, by- product, waste utilization, natural food additives

1. Introduction

Fruit and vegetable processing has increased considerably during the last 25 years. This has reflected the increase in demand for pre-processed and packaged food, particularly ready meals. During the period that many modern processes were developed and implemented, disposal of waste was not the major issue it is today. Competitive advantage was often achieved by exploiting the benefits of economies of scale, and strategies consequently involved the centralization of processing activities. This resulted in localized production of large tonnages of waste co-products. These were often disposed of relatively cheaply by landfill, land spreading, or selling as animal feed or for its production. However, subsequent to the Kyoto agreement, the issue of waste in our modern society has become more prominent since it contributes too many of the problems of global environmental sustainability. Vast quantities of food processing co-product wastes are produced throughout the world. For example over 5 million tons of sugar beet pulp, 3.5 million tons in brewers grain and nearly half a million tons of onion peeling waste are produced annually (Awarenet, 2004). For most fruits and vegetables, one can estimate the likely waste as approximately 30% or more of processed material or even in some processes; it may be up to 75%.

Nowadays, the high volume of waste produced marks food industry. According to the recent research conducted by FAO, about 1.3 billion tons of food has been wasted worldwide per year, which represents one-third of the total food industry production (Gustavsson *et al.* 2011). The largest amount of loss is verified by fruits and vegetables, representing 0.5 billion tons. In developing countries, fruit and vegetable losses are severe at the agricultural stage but are mainly explained by the processing step, which accounts for 25 % of losses (Gustavsson *et al.* 2011).

The growing, processing and preparation of fruit and vegetables result in the production of varying degree of waste material. The waste material may be in the form of leaf/straw, waste during harvesting, processing industry waste and after processing waste (Joshi and Devraj, 2008). The waste obtained from fruit processing industry is extremely diverse due to the use of wide variety of fruits and vegetables, the broad range of processes and the multiplicity of the product (William, 2005). Vegetables and some fruits yield between 25% and 30% of non-edible products (Ajila *et al.,* 2010). The full utilization of horticultural produce is a requirement and a demand that needs to be met by countries wishing to implement low-waste technology in their agribusiness

Depending on plant species, variety and tissue, high levels of health protecting antioxidants, such as vitamin C and E, phenolic compounds including phenyl-propanoids and flavonoids, and or carotenoids such as lycopene can be found. The waste materials such as peels, seeds and stones produced by the fruit and vegetable processing can be successfully used as a source of phytochemicals and antioxidants. The entire tissue of fruits and vegetables is rich in bioactive compounds, such as phenolic compounds, carotenoids, vitamins and in most cases, the wasted by products can present similar or even higher contents of antioxidant and antimicrobial compounds than the final produce can (Ayala-Zavala *et al.,* 2010). The new aspects concerning the use of these wastes as byproducts for further exploitation on the production of food additives or supplements with high nutritional value have gained increasing interest because these are high value products and their recovery may be economically attractive. The by-products represent an important source of sugars, minerals, organic acid, dietary fiber and phenolics, which have a wide range of action, which includes antiviral, antibacterial, cardio-protective and anti-mutagenic activities (Jasna *et al*., 2009). Because of increasing threat of infectious diseases, the need of the hour is to find natural agents with novel mechanism of action. Natural products provide unlimited opportunities for new drug leads because of the unmatched availability of chemical diversity. Fruit and vegetable peels are thrown into the environment as agro waste which can be utilized as a source of anti-microbes. However, there is currently no major exploitation of these sources, due to the poor understanding of their nutritional and economic value, adding that there is a great opportunity for agribusiness in the area. (Tuchila *etal,* 2008).

Utilization of those by-products as a valuable source of natural food additives appears to be a good alternative toward mitigation of environmental problems and for further exploitation of food additives or supplements having high nutritional value and economically attractive. The transformation of these by products into a “product” with high added value makes it possible for these companies to reduce their cost of treatment, and even to generate additional profits, and thus to improve their competitiveness In this context, the main goal of this review article is to highlight the potential of fruit and vegetable processing byproducts as a source of natural food additives for food industry. Furthermore it identify key knowledge gaps and areas where research and innovation may particularly address the challenge of reducing fruit and vegetable processing waste and possibility to use what was previously considered waste.

2. Generation of fruit and vegetables byproducts

In the horticultural sector, there has been a growth in both acreage and agricultural production to fulfill the requirements of global food demand (Schieber *et al.,* 2001). This intensity of production generates large amount of plant products, estimated to be around 800,000 tons/year of fresh fruits and vegetables, without considering the losses and wastage during processing. The full utilization of horticultural produce is a requirement and a demand that needs to be met by countries wishing to implement low-waste technology in their agribusiness

In many cases the raw fruit and vegetables is not consumed directly by humans, but first undergoes processing to separate the desired value product from other constituents of the plant (Ayala-Zavala *et al.,* 2010). Some examples of fruit byproducts that have found a successful opportunity at the secondary process of extraction of bioactive compounds are coffee, macadamia, mango, and papaya (Miljkovic & Bignami, 2002). Processing of coffee generally involves separating the desired beans from the byproducts of processing e.g., the so-called “coffee cherry,” which consists of the fruit skin and other undesirable constituents. On the other hand, macadamia is a fruit that contains an inner and outer shell, and a nut. Processing generally involves separating the valuable nut (main product) from the shells considered as byproducts. Also, pineapple, taro, papaya, and mango are typically appreciated for their flesh but processing of these crops involves separation and removal of the skin and seed byproducts. For instance, U.S. Patent application US 2002/0187239 A1 have proposed the use of coffee cherry, macadamia, mango, taro and papaya byproducts as a source of nutritional constituents (Miljkovic & Bignami, 2002).

Other successful examples of fruit byproducts that can show the profitability of the extraction of bioactive compounds are citrus and grapes. Citrus is the most abundant crop in the world. Its worldwide production is over 88×10^6 tons and one-third of the crop is processed. Oranges, lemons, grapefruits and mandarins represent approximately 98% of the entire industrialized crop. Citrus fruits are processed, mainly to obtain juice, but also, in the canning industry, to produce jam and segments of mandarin (Izquierdo & Sendra, 2003). Worldwide industrial citrus wastes may be estimated at more than 15×10^6 tons, as the amount of residues obtained from the fruits accounts for 50% of the original whole fruit mass, which are exploited by the chemical industry to extract flavonoids and essential oils (Marín *et al.,* 2007).

Grapes (Vitis vinifera L.) belong to the world's largest fruit crops with a global production of around 69×10^6 tons in 2006 (FAOSTAT, 2007). Since about 80% of the total amount is used in wine making, some 10 million tons of grapes arise within a few weeks of the harvest campaign. Seeds constitute a considerable proportion of the grape, ranging from 38–52% on a dry matter basis. The seed oil is rich in unsaturated fatty acids (particularly linoleic acid) and phenolic compounds and is produced in all Europe (Maier *et al.,* 2009)

Byproducts resulting from the processing of papaya, pineapple and mango represent approximately 10–60% of fruit weight. Several kinds of minimally processed fruits produced variable amount of byproducts to the extent even exceeding the edible portion depending on the fruit in question. (Foo *et al.,* 2010) patented an extract from the skin of passion fruit, which showed the effect of lowering blood pressure and serum nitric oxide levels, providing a hepato protective effect, as well as antioxidant and anti-inflammatory effects in mammals. Within the revised literature the number of studied byproduct sources has been augmented considerably, which is caused by the value of recycling and integral exploitation interest of the agri-food industry, but also increasing information on the specific location of active compounds (Peschel *et al.,* 2006).

In this context, the use of the entire plant tissue could have economic benefits to producers and a beneficial impact on the environment, leading to a greater diversity of products (Cerezal & Duarte, 2005). This situation can be extrapolated to different food processing areas, including the oils, jams, juices, nectars, wines, syrups and the fresh-cut fruit industry (Ayala- Zavala *et al.,* 2010). However, practical aspects that need to be considered include extraction efficiency, availability of sufficient raw materials, and toxicity or safety issues (Balasundram, Sundram, & Samman, 2006).

Table: 1- Typical percentage and nature of Fruits and vegetable processing wastes

Fruit and vegetables	Nature of waste	Production in tones	Approx.waste In %	Potential quantities of waste (tones)
Mango	Peel, stones	6987.7	45	3144.4
Banana	Peel	2378.0	35	832.3
Citrus	Peel, rag and seed	1211.9	50	606.0
Pineapple	Skin, core	75.7	33	24.7
Grapes	Stem, skin and seeds	565	20	-
Guavas	Peel and core and seeds	565	10	-
Peas	Shell	107.7	40	68.3
Tomato	Skin, core and seeds	464.5	20	90.3
Potato	Peel	2769.0	15	415.3
Onion	Outer leaves	1102.0	-	-
Apple	Peel, pomace and seeds	1376.0	-	412.0

Source: Gupta and Joshi, 2000.

3. Composition and functional compounds of fruit and vegetable by products

3.1. Chemical composition

The amount of pollution load and characteristics of the waste depend on the food being processed. Chemical composition of the wastes from fruits and vegetables show that it is a rich source of various nutrients. Some of these fruit and vegetable wastes are a rich source of vital constituents like carbohydrates, proteins, fats, minerals, fibers etc. Nutrient composition of some of the solid wastes from fruits and vegetables is given in the Table 1.

The association between the diet rich in fruits and vegetables and a decreased risk of cardiovascular diseases and certain forms of cancer is supported by considerable epidemiological evidence (Riboli and Norat, 2003). Different studies have shown that free radicals present in the human organs cause oxidative damage to various molecules, such as lipids, proteins and nucleic acids, and are thus involved in the initiation phase of the degenerative diseases. Phenolic and other phytochemical antioxidants found in fruits and vegetables are capable of neutralizing free radicals and may play a major role in the prevention of certain diseases (Kaur and Kapoor, 2001). Numerous studies have provided evidence for decreased risk of some chronic dis-eases e.g., some types of cancer, cardiovascular and neurodegenerative disorders with increased dietary intake of vegetables, fruits, teas, spices and other plant-based foods and supplements. The most abundant by-products of minimal processing of fresh-cut fruit and vegetable are peel and seed and those are reported to contain high amounts of phenolic compounds with antioxidant and antimicrobial properties (Muthuswamy *et al*., 2008).

Tables: 2- Chemical Composition of different fruit by products in grams per 100g

Waste	**Chemical composition in grams**					
	Moisture	Protein	fat	Minerals	Fiber	Carbohydrate
Apple pomace	_	2.99	1.71	1.65	16.16	17.35
Mango seed kernel	8.2	8.50	8.85	3.66	_	74.49
Jack fruit (inner and outer portion	8.5	7.50	11.82	6.50	30.77	14.16
Jack fruit seeds	64.5	6.60	0.40	1.20	1.50	25.80
Jack seed flour	77.0	2.64	0.28	0.71	1.02	18.12
Passion fruit peel	81.9	2.56	0.12	1.47	5.01	_
Banana peel	79.2	0.83	0.78	2.11	1.72	5.00
Sweet orange seeds	4.00	15.80	36.90	4.00	14.00	_
Watermelon seeds	4.3	34.10	52.60	3.70	0.80	4.50
Muskmelon seeds	6.8	21.00	33.00	4.00	30.00	_
Pumpkin seeds	6.0	29.50	35.0	4.55	12.00	12.53
Banana stem						
Central core	93.1	0.30	0.03	1.04	0.68	1.20
Outer hard Fibrous sheath	91.9	0.12	0.06	0.98	1.81	2.44
Press juice from stem	98.6	0.05	_	0.63	_	0.41

Source: Maini and Sethi, 2000.

3.2. Occurrence of functional compounds

The most common bioactive compounds present in fruits and vegetables are vitamins C, E, carotenoids, phenolic compounds and dietary fiber (Gonzalez-Aguilar *et al.,* 2008). As health related compounds, these have been attributed to lowering the risk of developing cancer, Alzheimer, cataracts and Parkinson, among others. These beneficial effects have been attributed mainly to their antioxidant and radical scavenging activities, which can delay or inhibit the oxidation of DNA, proteins and lipids. Indeed, these compounds have shown antimicrobial effects, playing an important role in fruits' protection against pathogenic agents, penetrating the cell membrane of microorganisms, causing lysis (Ayala-Zavala & González-Aguilar, 2011).

The content of functional compounds in different tissues of fruits and vegetables depends on the evaluated product (Soong & Barlow, 2004). In general, vitamin C is uniformly distributed in fruits, carotenoids occur mainly on the surface of the tissues such external pericarp and peel, while phenolic compounds are located preferentially in peel and seeds and in a lesser extent in the flesh (Kanatt *et al.,* 2010).

Flavonoids are polyphenols with diphenylpropane ($C_6C_3C_6$) skeletons (Alothman *et al.,* 2009). Among these compounds, mirecitine, mangiferin, gallic acid and hydrolysable tannins, which are most likely gallotannins, constitute the major antioxidant polyphenolics found in some fruits and vegetables (Gonzalez-Aguilar *et al.,* 2008). Papayas (Carica papaya cv. Maradol), pineapples (Ananas comosus cv. Premium cayenne), and mangoes (Mangifera indica cv. Kent), analyzed for the phytochemical content and antioxidant status, corroborated the above information (Ayala-Zavala *et al.,* 2010). The peel and seed of mango showed the highest values of bioactive compounds and antioxidant capacity. The peel presented values of 5.997mg of gallic acid/g of fresh weight (fw), 4.455 mg of quercetin/g fw and 47.97% DPPH radical scavenging activity at the concentration of 322 mg/mL. On the other hand, the seed showed 37.279 mg of gallic acid/g, 35.954 mg of quercetin/g on a fresh weight basis and 93.4% of DPPH radical scavenging activity at the concentration 307 mg/mL, corresponding to the content of total phenolics, total flavonoids and antioxidant capacity, respectively. Phenolic compounds appear to be responsible for the high free radical inhibition activity, because samples that showed the lowest contents of phenolics and flavonoids also showed the lowest percentage of radical inhibition (Ayala-Zavala *et al.,* 2010).

Soong and Barlow (2004), evaluated the antioxidant capacity and phenolic contents of seed and pulp of avocado, jackfruit, longan and mango, using ABTS (2,2-azinobis-3-ethylbenzothiazoline-6-sulfonic acid), FRAP (ferric-reducing antioxidant power) and FCR (Folin– Ciocalteu reagent) methods. This study showed that the seeds of these fruits had a higher antioxidant capacity and phenolic content than the pulp. The ABTS, FRAP and FCR values for the seeds of mango, longan, avocado, and jackfruit were: 762, 448, 236.1 and 7.4 μmol of ascorbic acid/g; 2572, 1388, 1484 and 2.8 μmol of gallic acid equivalents/g and 117, 62.6, 88.6 and 27.2 mg of gallic acid equivalents/g, respectively. The ABTS, FRAP and FCR values for the pulp of mango, longan, avocado, and jackfruit were: 7.2, 3.7, 4.9 and 3.0 μmol of ascorbic acid/ g; 36.6, 41.5, 9.6 and 6.8 μmol of gallic acid equivalents/g and 2.4, 1.6, 1.3 and 0.90 mg of gallic acid equivalents/g, respectively.

Ribeiro *et al.,* (2008) found that the peel and seed of "Uba" Mango had a total phenolic content of 0.0572 mg/g and 0.08254 mg/g of dry matter, these values were 4.6 and 7.3 times higher than those in the pulp, respectively. It was also found that the phenolic content in the peel of this mango cultivar was 3.3 times higher than that found in apple peel. DPPH radical scavenging activity of mango peel showed a higher inhibition value (53.3%) followed by the seed (24.2%) and finally the pulp. This higher antioxidant activity of the peel was related to the higher content of antioxidant compounds in comparison to other parts of the fruit.

The antioxidant capacity of seed, peel and pulp of eight varieties of avocado was determined. For all cultivars, seeds contained the highest total phenolic contents and antioxidant capacities, where as the pulp had the lowest. Total phenolic contents in the seeds ranged from 19.2 to 51.6 mg of gallic acid equivalents/g. "Hass" avocado contained higher phenolic content and antioxidant capacities than all the non-Hass cultivars (Wang, Bostic, & GU, 2010). Similarly, other studies have also reported that the phenolic content of pomegranate peels was 10 times higher (249.4 mg/g) than that found in the pulp (24.4 mg/g) (Li *et al.,* 2006). Considering that peels and seeds of most exotic fruits are not consumed and rarely approached, the high amount of bioactive compounds presented in these non-edible parts could be used for different purposes in the food industry such as enrichment or development of new products.

Carotenoids are phytochemicals presented in considerable amount in fruit tissue (Rufino *et al.,* 2010). Carotenoids play a potentially important role in human health by acting as biological antioxidants, protecting cells and tissues from the damaging effects of free radicals and singlet oxygen and are used as natural colorants in the food industry (Oreopoulou & Tzia, 2007). The carotenoid content was found to be 4–8 times higher in ripe mango peels compared to raw fruit peels (Ajila *et al.,* 2007).

The crude fiber contents of mango peel represent mainly cellulose fractions, which is a major part of insoluble dietary fiber (Ajila *et al.,* 2010). The dietary fiber content in mango peels of different varieties has been estimated. The total dietary fiber content in dry peel varied from 45% to 78% (Ajila *et al.,* 2010). The soluble dietary fiber content in both rawand ripe mangos peels aremore than 35% of total dietary fiber. Insoluble dietary fiber relates to both water absorption and intestinal regulation whereas soluble dietary fiber associates with cholesterol in blood and diminishes its intestinal absorption (Palafox-Carlos *et al.,* 2010). The characteristic feature of some tropical exotic fruit byproducts like mango peel is that it has high contents of soluble dietary fiber, which is reported to have more health beneficial effects. The waste generated during the processing of passion fruit mainly consists of peel and seed. Dietary fiber from yellow passion fruit (Passiflora edulis) peel was reported to be prepared as an alcohol insoluble material which may be suitable to protect against diverticular diseases (Yapo & Koffi, 2008).

Another bioactive attribute of exotic fruit byproducts are their antibiotic properties. The peel and seed of three varieties of avocado (Shepard, Hass and Fuerte) showed activity against yeast, gram negative and gram-positive bacteria (Chia, Wah, & Dykes, 2010). The peel and seed extracts of avocado Hass with a minimum inhibitory concentration value of 104.2 μg/mL is the most effective against Salmonella enteriditis and Zygosaccharomyces bailii, respectively (Chia *et al.,* 2010).

Despite the high content of bioactive compounds in the skins and seeds of exotic fruits, attention must be paid to antinutritional and toxic factors, like high tannin content in these tissues (Abdalla *et al.,* 2007). Tannins are considered nutritionally undesirable because they precipitate proteins, inhibit digestive enzymes and affect the utilization of vitamins and minerals. However, many tannin molecules have been reported to reduce the mutagenicity of a number of compounds and it all depends on the concentration at which it is used or consumed. To avoid these problems it is recommended that during the preparation of extracts from these byproducts, acidic and/or alkaline hydrolysis are recommended in order to inactivate these compounds.

Table: 3-Functional compounds found in different tissues of fruit

Fruit	part of the fruit	Phenolics (mg/100g)	Ascorbic acid (mg/100g)	Carotenoids (µg/100 g)	Fiber (mg/100 g)	Référence
	Seed	5160**	_	630*	_	Leong and Shui (2002); Wang et al. (2010)
	pulp	490**	9**	590**	5000**	
Avocado	Peel	1260*	_	1520*	_	
	pulp	232*	12.7**	75**	4000**	Someya,Yoshiki, and Okubo (2002)
Banana	peel	928*	_	400**	7680**	
	Seed	_	_	_	_	Charoensiri, Kongkachuichai, Suknicom, and Sungpuag(2009)
	pulp	159.93*	144**	13,800*	5400**	
Guava	peel	5870**	_	_	_	
	Seed	2770*	_	1910*	_	Mahattanatawee et al. (2006)
	pulp	90*	8.0–10**	4530*	1600**	
Jackfruit	peel	_	_	_	_	
	Seed	6260*	_	_	_	Soong and Barlow (2004)
	pulp	160*	60.1**	_	1100**	
Longan	peel	_	_	_	_	
	Seed	11,700.0*	_		_	Leong and Shui (2002)
	pulp	240.0*	19.7**	4530**	1000.0**	
Mango	peel	7000.0**	_	_	28,100.0*	
	Seed	_	_	_	_	Al-Ani, and Al-Shuaibi (2009)
Pomegranate	pulp	24,990.0**	16**	_	_	
	Peel	2440.0**	10,200.0**	_	300.0**	

- No results were found.
*Dry weight.
**Fresh weight

3.3. Potential of fruit by-products as a source of food additives

Fruit production, trade and consumption have increased significantly on the domestic and international markets due to their attractive sensory properties and a growing recognition of its nutritional and therapeutic value (Bicas *et al.,* 2011).In many cases the raw fruit is not consumed directly by humans, but first undergoes processing to separate the desired value product from other constituents of the plant tissue. For instance, processing of coffee generally involves separating the desired beans from the byproducts of processing, which consist of the fruit skin and other undesirable constituents (Vignoli *et al.,* 2010). Likewise, tropical crops such as pineapple, taro, papaya, and mango are typically valued for their fruit. Processing of these crops typically involves separating the valuable fruit part from byproducts such as skin and seeds (González- Aguilar *et al.,* 2010).

The mass of byproducts obtained as a result of processing tropical exotic crops may approach or even exceed that of the corresponding valuable product, affecting the economics of growing tropical exotic crops (Miljkovic & Bignami, 2002). In the past, this costly problem has been mitigated to some extent by processing the byproducts further to yield a product that presents less of a disposal problem or that has some marginal economic value (Sun-Waterhouse, Wen, Wibisono, Melton, &Wadhwa, 2009). The economics of processing tropical crops could be improved by developing higher-value use for their byproducts. For instance, several patents have been published relating the use of tropical crops as a source of nutraceutical compounds (Garrity *et al.,* 2008). It has now been reported that the byproducts of tropical exotic fruits contain high levels of various health enhancing substances that can be extracted from the byproducts to provide nutraceuticals (Gorinstein *et al.,* 2011).

Fruit by products have a potential role in food industry; where one of the majors can be as food additives (antioxidants, antimicrobials, colorants, flavorings, and thickener agents). Vitamin C, a natural compound obtained from several plant tissues is the best example of the potential use in the food industry. The antimicrobial power of plant and herb extracts has been recognized for centuries, and mainly used as natural medicine, however, the trends in using these compounds as food preservatives is increasing now days (Ayala-Zavala & González-Aguilar, 2011). In addition, plants produce a wide range of volatile compounds, some of which are important for flavor quality factors in fruits, vegetables, spices, and herbs. Ever since, natural colors from spices and herbs as well as fruits and vegetables have been part of the everyday diet of humans. It is well known that agro industrial byproducts are rich in dietary fibers (DF). The DF additive provides economic benefits to the food, cosmetic and pharmaceutical industries (Ajila *et al.,* 2010). Apart from the well-known health effects, DF shows some functional properties as food additives, such as water-holding capacity, swelling capacity, increasing viscosity or gel formation, which are essential in formulating certain food products.

On the other hand, foods are perishable products as a cause of their intrinsic characteristics. Microbial growth, sensorial attribute decay, and loss of nutrients are amongst the major causes that compromise the quality and safety of food produce (Janevska *et al.,* 2010). Chemical synthetic additives can reduce food decay, but consumers are concerned about chemical residues in the products (Ayala-Zavala & González-Aguilar, 2011). Regarding the food safety issues, one of the major emerging technologies is the application of natural additives.

We have to consider that the high content of bioactive compounds present in fruit byproducts can be used as natural food additives. If this approach is realized, it would be feasible to fulfill the requirements of consumers for natural and preserved healthy food. In addition, the full utilization of fruits could lead the industry to a lower-waste agribusiness, and increasing industrial profitability.

3.4. Potential of vegetables by-products as a source of food additives

The amount of vegetable residues generated after harvesting the edible portion of most crops can account for a large proportion depending on the plant (Kumar *et al*., 2000). Traditionally, agro-industrial waste has been used as a feed or as a fertilizer.

However, vegetable by-products are an important resource as a raw material for potential use in food additives or dietary supplements and as a source of extractable polysaccharides for industrial explotation. A major component of plant by-products is dietary fibre (Laufenberg *et al*., 2002). Dietary fibre with associated polyphenols has also been obtained from plant wastes (Larrauri *et al*., 2007). Others are minor bioactive components such as: carotenoids, phytoestrogens, etc (Llorach *et al*., 2002). Vegetable residues as a source of natural antioxidants (Moure *et al*., 2001) and functional compounds (Fischbach, *et al*., 2000), have recently been reviewed. Besides preparation of value-added products, the utilization of residues represents a good solution to avoid environmental pollution.

Yet, another group of interesting compounds that could be obtained from plant wastes are low molecular weight carbohydrates (LMWC; mono-, di- and oligosaccharides). Nevertheless, there are not many reports in the literature dealing with the use of vegetable residues as a raw material for the preparation of LMWC. Indigestible carbohydrates, such as non-digestible oligosaccharides, are currently considered prebiotics because of they reach the colon undigested, where mainly bifidobacteria and lactic acid bacteria, thus producing a health positive effect (Kadirvelu *et al.,*), ferment them. Extraction and characterization of LMWC from several vegetable residues by high performance liquid chromatography (HPLC), is to utilize them as a source of prebiotic ingredients.

4. Possible uses of fruit and vegetables byproducts in the food industry

Several potential uses can be considered for fruit and vegetable byproducts, one of the majors can be as food additives (antimicrobials, antioxidants, colorants, flavorings, and thickener agents) (Ayala-Zavala & González-Aguilar, 2011). However, it can be observed in the next section that very few studies on the use of tropical exotic fruit byproducts have been performed to accomplish this goal; however, other fruits have been used.

4.1. As anti-browning additives

Fruit and vegetables byproducts are sources of a great variety of antioxidants, and their particular properties may be useful in maintaining food quality avoiding enzymatic browning in fruits. The enzymatic browning caused by polyphenol oxidase (PPO) is a major detrimental factor of the quality of fresh-cut fruits and vegetables (Gonzalez-Aguilar *et al.*, 2000). To avoid this problem, several additives have been applied mainly by dipping, spraying or vacuum impregnation. Antioxidants from fruit and vegetables byproducts may be grouped in accordance to their mode of action, i.e., as acidulants, reducing and/or chelating agents and enzyme inhibitors. Therefore their beneficial effects may differ among treated product and matrix applied.

The optimum pH for polyphenoloxidase activity has been reported to be from acid to neutral in most fruits and vegetables, and the optimum activity is observed at pH 6.0–6.5 while the minimum activity is detected below pH 4.5. This is the reason behind the use of chemicals that decrease the product's pH or acidulants to control the enzymatic browning. Acidulants are used in conjunction with other treatments because reducing browning by controlling only the pH is difficult. Acidulants, such as citric, malic, and phosphoric acids, are capable of lowering the pH of a system, thus reducing the polyphenoloxidase activity (Rojas-Graü *et al.,* 2007).

Gorny *et al.,* (2002) determined that 2% ascorbic acid with 1% calcium lactate reduced the browning of fresh-cut peaches initially, but after 8 days at 0 °C the difference was minimal with respect to non-treated peaches. They also found that 2% ascorbic acid was effective in reducing the browning of fresh-cut Fuji apple slices when combined with low oxygen atmosphere storage. Gonzalez-Aguilar *et al.,* (2005) compared N-acetyl cysteine with ascorbic acid and iso ascorbic acid as anti-browning agents for fresh-cut pineapple stored for 14 days at 10 °C While the treatment with N-acetyl-cysteine (0.05 M) was the most effective in reducing browning and better appearance, higher levels of sugars and vitamin C (0.05M) resulted from iso ascorbic acid (0.1M) and ascorbic acid. The level of anti-browning agents used, did not affect other sensory characteristics. Also, the combination of citric acid and ascorbic acid showed effective results. When 3% ascorbic acid+1% citric acid+1% sodium hexametaphosphate that had a pH of 2.9 was applied to fresh cut apples, sodium hexametaphosphate induced tissue breakdown in both varieties tested but only at 10 °C. No formal sensory evaluation was performed but some sour flavor was detected (Pilizota & Sapers, 2004). Extracts frompalo fierro (desert ironweed) rich in phenolic compounds prevented apple juice browning but in a lesser extent than other tested antioxidants like hexylresorcinol and cystein (de la Rosa *et al.,* 2011).

On the other hand, it is important to mention the plant phenolic compounds as a large group of natural antioxidants ubiquitous in a diet high in fruits (Arts & Hollman, 2005). These compounds are divided in two groups: phenolic acid and flavonoids, which both exhibit remarkable antioxidant activity (Palafox-Carlos *et al.,* 2010). Fruits like mango, kiwi, guava, red dragon, papaya, longan and sapodilla exhibit important antioxidant capacity and significant polyphenol contents among other fruits (Mahattanatawee *et al.,* 2006). Certainly, these compounds are a serious candidate to be applied as additives in food products to preserve and enhance quality, avoiding food oxidation. However, there are no studies approaching aspects such as anti-browning effects and antioxidant benefits of phenolic compounds applied on food products. This is a topic that needs attention to find new applications and uses of fruits and vegetables as sources of these compounds.

4.2. As antimicrobial and flavoring agents

Natural antimicrobial compounds are a re-emerging alternative to food preservation. The antimicrobial power of plant and herb extracts has been recognized for centuries, and mainly used as natural medicine. The most studied natural antimicrobial compounds in plant extracts are essential oils (EOs). Essential oils are volatile, natural, complex compounds characterized by a strong odor and are formed by aromatic plants as secondary metabolites (Bakkali *et al.,* 2008). Among EO constituents we found terpenes, which form structurally and functionally different classes. They are made from combinations of several 5-carbon-base units called isoprene. Evidence about the antimicrobial activity of terpenes has been well demonstrated. Terpenes or terpenoids are active against bacteria (Amaral *et al.,* 1998), fungi (Ayafor *et al.,* 1994), virus (Hasegawa *et al.,* 1994) and protozoa (Cowan, 1999). It was reported that 60% of EO derivatives examined to date were inhibitory to fungi while 30% inhibited bacteria. To date, the mechanism behind the antimicrobial activity of terpenes is unclear. The generally accepted hypothesis establishes that EOs comprises a large number of components and it is likely that their mode of action involves several targets in the bacterial cell. The hydrophobicity of EOs enables them to partition in the lipids of the cell membrane and mitochondria, rendering them permeable and leading to leakage of cell contents. Physical conditions that improve the action of EOs are low pH, low temperature and low oxygen levels (Burt, 2004). In addition plant volatiles have been widely used as food flavoring agents, and many are generally recognized as safe (GRAS).

The citrus industry produced large amounts of byproducts. Oils obtained from skin have been used for different applications. Studies of the application of lemon extract on dairy products have also been performed (Conte *et al.,* 2007). Different antimicrobial packaging systems including lemon extracts have been used to preserve Mozzarella cheese. Results showed an increase in the shelf life of all active packaged Mozzarella cheeses, confirming that lemon extract may exert an inhibitory effect on the microorganisms responsible for spoilage phenomena without affecting the functional microbiota of the product (Conte *et al.,* 2007).

The antimicrobial and antioxidant potentials of pomegranate peel and seed extract were investigated in chicken products (Kanatt *et al.,* 2010). Pomegranate peel extract (PE) showed excellent antioxidant activity while the seed extract did not have any significant activity, probably to the difference in the type and amount of bioactive compounds present in both tissues. Pomegranate peel extract showed good antimicrobial activity against Staphylococcus aureus and Bacillus cereus. In general, addition of pomegranate peel extract to popular chicken and meat products enhanced its shelf life by 2–3 weeks, during chilling temperature storage. PE was also effective in controlling oxidative rancidity in these chicken products (Kanatt *et al.,* 2010).

Since the antimicrobial activity of EOs has been demonstrated, consequently tremendous potential and application opportunities are approaching. Studies with fresh meat, meat products, fish, milk, dairy products, vegetables, fruit and cooked rice have shown that the concentration needed to achieve a significant antibacterial effect is around 0.5–20 μL g^{-1} in foods and about 0.1–10 μL mL^{-1} in solutions for washing fruit and vegetables (Burt, 2004). Synergism has been observed between carvacrol and its precursor p-cymene and between cinnamaldehyde and eugenol. Synergy between EO components and mild preservation methods has also been observed. Some EO components are legally registered flavorings in the EU and the USA. However, undesirable sensorial effects can be a limiting factor and careful selection of type and concentration of EOs according to the type of food must be considered (Burt, 2004).

On the other hand, phenolic compounds have demonstrated remarkable antimicrobial activity. Some of the molecules consist of a single substituted phenolic ring with some hydroxyl groups like cinnamic and caffeic acids (Dorman & Deans, 2000). Others like flavonoids present three phenolic rings with several hydroxyl groups. The site(s) and number of hydroxyl groups on the phenol group are thought to be related to their antioxidant and antimicrobial capacity and relative toxicity to microorganisms, with evidence that increased hydroxylation results in increased microbial toxicity (Cowan, 1999).

Some studies about the antimicrobial activity of phenolic extract from exotic fruits have been achieved as follows. The antimicrobial properties of mango seed kernel phenolic extracts were investigated. Minimum inhibitory concentrations of the mango kernel extract against 18 species of 43 strains, containing food-borne pathogenic bacteria were determined using the agar dilution method. The mango kernel extracts had a broad antimicrobial spectrum, and was more active against gram-positive than gram-negative bacteria with a few exceptions. These results also indicated that the active component of the Mango Kernel extract was a type of polyphenol (Kabuki *et al.,* 2000). Water infusion of Cocos nucifera L. husk fiber has been used in northeastern Brazil traditional medicine for treatment of diarrhea and arthritis. The crude extract rich in catechin revealed antimicrobial and antiviral activities. Catechin and epicatechin together with condensed tannins (B-type procyanidins) were demonstrated to be the components of the water extract from Cocos by-products (Esquenazi *et al.,* 2002).

Mandalari *et al.,* (2007) evaluated a flavonoids-rich extract from the peel of Bergamot citrus fruit, an important byproduct in the processing industry, against different bacteria and yeast. The enzyme preparation pectinase 62L efficiently converted common glycosides into their aglycones from bergamot extracts, and this deglycosylation increased the antimicrobial potency of Citrus flavonoids. Pair wise combinations of eriodictyol, naringenin and hesperidins showed both synergistic and indifferent interactions that were dependent on the test indicator organism. This study concluded that Bergamot peel is a potential source of natural antimicrobials that are active against gram-negative bacteria.

The antimicrobial activities of quince (Cydonia oblonga Miller) fruit have also been evaluated. Chlorogenic acid (5-O-caffeoylquinic acid) was the most abundant phenolic compound in the pulp (37%), whereas rutin (quercetin 3-O-rutinoside) was in the peel (36%). Quince peel extract was the most effective for inhibiting bacteria growth, it seems that flavonoids in the peel in conjunction with chlorogenic acid acts in synergism inhibiting antimicrobial growth (Fattouch *et al.,* 2008).

In this context, the exotic fruits and moreover their byproducts, are promising new sources of phenolic antimicrobial compounds, offering new commercial opportunities to food industries. However, to date there are very scarce information and studies on EOs extracted from fruit and vegetables byproducts and their application in food products. This is an important area of research that needs immediate attention.

4.3. As a source of colorants

Color is one of the most important quality attributes for the food industry. While synthetic pigments are increasingly rejected by the consumer and are supposed to be unwholesome, proven or not, the acceptance of natural or nature-derived alternatives is promoted by their psychological comprehension of being healthy and of good quality (Stintzing & Carle, 2004). Ever since, natural colors from spices and herbs, fruits and vegetables have been part of the everyday diet of humans.

Fruit and vegetables byproducts have become into an important source of those pigments and colors, mainly because they present high color stability and purity. Further criteria toward new viable sources of natural pigments are: good availability, a low price and high yielding material (Stintzing & Carle, 2004). All those characteristics can easily be presented in fruit byproducts.

Anthocyanins are important colorants and can be extracted principally from plant byproducts such as grape pomace or banana bracts (Stintzing & Carle, 2004). Commonly applied preparations obtained from byproducts include red cabbage, red radish, purple sweet potato, black carrot, aronia, cherry, elderberry and blackberry. In general, vegetable sources such as radish, purple sweet potato, red-fleshed potato, or red cabbage have been shown to provide a higher percentage of acylated anthocyanins than fruits which reflects in higher tinctorial strength of the respective extracts at food pH (Stintzing & Carle, 2004). Amongst fruits acerola, guajiru, jambolao, jussara and acai have shown to be a good source of anthocyanins and other flavonoids (de Brito *et al.,* 2007).

4.4. As source of dietary fiber

It is well known that agro industrial byproducts are rich in dietary fibers (DF). DF in byproducts contained attached appreciable amount of colorants, antioxidant compounds or other substances with positive health effects, while some of them, like the oilseed meals, are rich in proteins. The DF additive provides economic benefits to the food, cosmetic and pharmaceutical industries (Ajila *et al.,* 2010). Apart from well known health effects, DF show some functional properties, such as water-holding capacity, swelling capacity, increasing viscosity or gel formation which are essential in formulating certain food products. Formulated food products with high dietary fiber contents are now commercially available. DF incorporated in these products is obtained mainly by cereals. However, the use of byproducts from other fruits and vegetables seems promising, since all these materials are rich in soluble dietary fibers.

Byproducts, rich in dietary fiber are a prize to food processors, especially since consumers prefer natural supplements, fearing that synthetic ingredients may be the source of toxicity. Also, DF possesses remarkable beneficial nutritive and human protective effects, such as prevention of colon cancer and diverse types of cardiovascular diseases (Palafox-Carlos *et al.,* 2010). Incorporation of rich-fiber byproducts, including wheat bran in breakfast cereals, rice bran, sugarcane bagasse, wheat bran in bread and peach dietary fiber concentrate in jam have been investigated (Elleuch *et al.,* 2011). DF from different sources has been included in different functional food such as bar fruits, bread, beverages and other processed foods.

In real terms, the fiber from fruit and vegetables byproducts may be of great interest to the food technologist. Fruits and vegetable exhibit the important content of DF. Amongst the fruits with major fiber content includes guava, carambola, mamey, mango, sapodilla and raspberries (2.70, 2.78, 3.0, 3.10, 5.31 and 6.50 g/100 g, respectively) (USDA, 2010). The food industry can take advantage of the physicochemical properties of fiber to improve the viscosity, texture, sensory characteristics and shelf-life of their products (Elleuch *et al.,* 2011).

Additionally, fiber-rich byproducts may be incorporated into food products as inexpensive, non-caloric bulking agents for partial replacement of flour, fat or sugar, and enhances water and oil retention to improve emulsion or oxidative stabilities (Elleuch *et al.,* 2011). However, the percentage of fiber that may be added to foods is finite, because it can cause undesirable changes in color, taste and texture of foods (Elleuch *et al.,* 2011).

The literatures contain many reports about addition of dietary fiber to food products such as baked goods, beverages, confectionery, dairy, frozen dairies, meat, pasta and soups. Most commonly, dietary fibers are incorporated into bakery products to prolong freshness, thanks to their capacity to retain water, thereby reducing economic losses and at the same time to enhance digestion. Muffin batter supplemented with peach dietary fiber, and cake dough enhanced with prickly pear cladode fiber at levels up to 5% were deemed as acceptable as the control, based on sensory scores reported by consumer panelists (Ayadi *etal.,* 2009). Other studies, mainly on breads for special diets, have shown that the addition of dietary fiber from maize and oat in gluten-free formulations gave breads with significantly higher loaf volume and crumb softness, compared to the control non-fiber gluten-free bread, improving their acceptability (Sabanis, Lebesi, & Tzia, 2009).

The use of fibers in dairy products is also widespread (Elleuchet *etal.,* 2011): e.g. fiber improves the texture of ice cream, providing a uniformly smooth bulk, desirable resistance to melting, and improves handling properties primarily by hindering crystal growth, as temperature fluctuates during storage (Soukoulis, Lebesi, and Tzia (2009). They also showed the potential use of dietary fibers (oat, wheat, apple and inulin) as crystallization and re-crystallization controllers in frozen dairy products.

Antioxidant capacity is another important property of DF that is given by the presence of different antioxidant linked compounds. Antioxidants associated with the dietary fiber matrix are substances that are not detected in the usual analytical procedures for either dietary antioxidants (targeting antioxidants extracted by aqueous organic solvents) or DF (targeting carbohydrates and lignin) quantification. However, these antioxidant compounds make up a substantial portion of the dietary antioxidant capacity; they are not minor constituents of DF, and as such they may contribute significantly to the health effects attributed to DF and dietary antioxidants (Saura- Calixto, 2011).

In this perspective, fruits and vegetable and their byproducts could be seriously taken into consideration to be utilized as valuable sources of DF useful for several applications in the food industry. However, it is necessary to advance the practices of DF extraction as DF from fruits and vegetable is extracted and may successfully be implemented in diverse innovative applications in food products. Utilization of fibers from fruit and vegetables byproducts would not only open new businesses and profits, but would also contribute to give alternate uses to the huge quantities of the byproducts wasted in the food industry.

Table: 4- proportion of dietary fiber of different fruit and vegetable pomace in gram 100gram of dry matter

Pomace	Proportion in grams				
	NDF	ADF	cellulose	Hemicellulose	Lignin
Idared apple	$24.20^{h}\pm0.54$	$19.81^{f}\pm1.74$	$3.64^{g}\pm1.24$	$4.26^{d}\pm1.45$	$6.17^{f}\pm1.32$
Champion apple	$31.27^{f}\pm0.28$	$21.90^{ef}\pm1.43$	16.10e ±0.90	$9.37^{c}\pm1.1$	$5.80^{fg}\pm0.98$
Ducat strawberry	$55.19^{d}\pm0.37$	$45.05^{c}\pm1.38$	29.35b ±1.02	$10.13^{c}\pm1.07$	$15.70^{d,e}\pm0.83$
Kent strawberry	$58.25^{c}\pm0.67$	$46.70^{c}\pm0.64$	25.86c ±0.78	$1.55^{e}\pm0.21$	$20.84^{c}\pm0.15$
Chokeberry	$87.48^{a}\pm0.60$	$57.24^{a}\pm2.05$	34.56a ±1.26	$30.24^{a}\pm0.82$	$22.68^{b}\pm0.25$
Black currant	$63.55^{b}\pm0.66$	$47.67^{b}\pm0.94$	21.01d ±0.88	15.87b ±0.32	$26.66^{a}\pm0.11$
Black carrot	$28.55^{g}\pm0.62$	$23.57^{e}\pm0.52$	16.28e ±0.91	$4.98^{d}\pm0.1$	$7.29^{f}\pm1.06$
Dolanka carrot	$18.05^{i}\pm0.69$	$16.02^{g}\pm0.75$	12.65f ±0.91	$2.03^{e}\pm0.22$	$3.37^{h}\pm0.86$
Red cabbage	$34.76^{e}\pm0.87$	$29.33^{d}\pm1.04$	15.21e ±0.89	$5.43^{d}\pm0.27$	$14.12^{e}\pm0.65$

*Mean of three replications; if different within a column, indicates significant difference (_ £ 0.05).
Source: Agnieszka Nawirska, Cecylia Uklanska, 2008

4.5. As sources of protein

Increased industrial demands for new sources of good quality protein at a competitive cost have generated great deal of research efforts using plant proteins. Plant proteins, especially those originating from agro industrial by-products, are in recent research attention. Interestingly, fruits and vegetable-processing industries are known to produce significant amounts of solid wastes such as seeds that might be of commercial significance as sources of protein.

Serious protein deficiencies and the high costs of animal protein sources have stimulated research on developing new sources of protein from unexploited sources or wastes and by-products (Perumal *et al.,* 2001). Utilization of these fruit and vegetables processing by-products (usually seeds and skin), which is available at no additional cost, can contribute to the generation of value-added protein adjunct together with its implication in reducing solid waste and, thus, can contribute to generating environmental sustainability. The most fruit seed is currently a waste product as it is often discarded after eaten or processed. according to (Imaga *et al.,*2009) papaya seeds constitute 22% of the waste from papaya puree plants papaya seeds are recently gaining importance due to its medicinal value, since it recently had been used in curing sickle cell diseases, poisoning related renal disorder (Imaga *et al.,*2009) and as anti-helminthes (Okeniyi *et al.,*2007). Also, increasing growth of orange processing industries result in producing large quantities of orange seeds as by-product necessitate the determination of the potential of orange seed utilization in human and /or animal diets (Akpata *e tal.*.1999).

Table: 5- Amino acids scores of selected seed and kernel flours

Amino acids	Amino acid score							
	Papaya	Apple	Watermelon	Guava	Orange	Prickly pear	Apricot	Paprika
Leucine	161.67	140.00	121.29	127.29	82.08	153.33	71.88	116.88
Isoleucine	76.43	78.10	72.86	76.43	52.14	109.52	110.00	96.67
Methionine	60.91	41.82	58.64	185.91	50.91	29.55	55.45	53.64
Phenylalanine	122.86	150.36	161.43	101.07	109.29	133.93	242.14	154.29
Lysine	101.19	58.10	113.10	15.71	42.38	116.43	46.67	193.57
Threonine	72.00	64.00	85.25	98.00	46.50	32.75	22.75	123.75
Tyrosine	53.41	88.29	69.27	84.15	40.98	56.34	149.51	100.24
Valine	55.00	93.33	77.14	116.19	73.10	103.57	122.41	103.10

Source: F. Samia El-Safy *et al.,* 2012

5. Summary and Conclusion

The mass of by-product obtained because of processing fruit and vegetables may approach or even exceed that of the corresponding valuables products affecting the economics of growing horticultural produce. The failure or inability to salvage and reuse such materials economically results in the unnecessary waste and depletion of natural resources. Therefore, the possibility of creating alternative processes to give benefit to this wasted material must be considered.

A substantial part of the waste produced during the handling and processing of fruits and vegetables still comprises important amounts of the original plant materials, such as skins, fruit seeds, leaves, stems, barks, and roots. High-value natural compounds can be found in most of these fruit and vegetable residues, many of them having health-promoting characteristics. Therefore, transformation of these wastes into wealth makes it possible for fruit and vegetable processing companies to improve their competitiveness. Amongst the possible uses of these compounds that can be found in the food industry are as antioxidants, antimicrobials, flavoring, colorants, texturizer, source of dietary fiber and proteins they added. This scenario helps the fruit and vegetable processing companies to reduce their cost of treatment, and even to generate additional profits from what was previously considered waste, and thus to improve their competitiveness.

The combined efforts of waste minimization during the production process, environmentally friendly preservation of the product, and utilization of by product would substantially reduce the amount of waste, as well as boost the environmental profile of fruit and vegetable processing industry. This suggests that the by-product from fruit and vegetables should be further utilized as a potential source for functional food ingredients, natural antioxidants, antimicrobial compounds, and, in addition, it could be further processed into therapeutic functional food products rather than just discarded as waste.

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